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QUARRYING AND CRUSHING METHODS AND COSTS AT THE PLAINVILLE, (CONN.,) TRAP-ROCK QUARRY OF THE NEW HAVEN TRAP ROCK CO., NEW BRITAIN, CONN.

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QUARRYING AND CRUSHING METHODS AND COSTS AT THE PLAINVILLE, CONN., TRAP-ROCK QUARRY OF THE NEW HAVEN TRAP ROCK CO., NEW BRITAIN, CONN. [1]

By A. L. Worthen[2]

INTRODUCTION

This is one of a series of papers being published by the United States Bureau of Mines, describing mining and milling methods at crushed-stone plants throughout the United States. These papers are designed to disseminate technical information regarding the methods used. The cost tabulations represent operating expenditures only and not total production costs. Although the publication of total production costs might not be advisable in some instances, yet a knowledge of operating costs is essential to the technical discussion and study of the methods employed. The attention of the reader is specifically called to this differentiation in order that there will be no misunderstanding of the scope of the cost tabulations.

This paper deals with the quarrying and crushing methods used at the Plainville plant of the New Haven Trap Rock Co., which produces annually between 275,000 and 300,000 tons of trap rock. Although not the largest quarry operated by the company, it typifies the standard methods used by all the quarries in producing crushed stone and has one or two rather unique operating features. The cost of production at this plant is close to the average cost at all quarries of the company.

The plant is located on the Plainville-New Britain Turnpike about 2 1/2 miles from the center of Plainville and 2 1/2 miles from New Britain. It has rail connections at Cook's Siding on the Western Division of the New York, New Haven & Hartford Railroad. (See fig. 1.)

The production period is usually from April 1 to December 1. Any tonnage required during the rest of the year is shipped from storage, and the shut-down period is utilized to make necessary repairs and alterations to the equipment.

ACKNOWLEDGMENTS

The author received the invaluable assistance of many members of his organization in the preparation of this paper. R. D. Brewer, superintendent of of the Plainville plant, was especially helpful. His cooperation in supplying much of the information contained herein is deeply appreciated, as is also the assistance of T. W. Jones, safety engineer, who spent much of his time gathering material for this report.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6920."

[2] One of the consulting engineers, U. S. Bureau of Mines.

Grateful appreciation is extended to others whose reports and maps are used and to whom further reference is made in this paper.

BRIEF HISTORY AND EARLY DEVELOPMENT

The quarry was first operated about 1895 by J. H. Cooke, and in 1898 J. W. Cooke and C. S. Tinker were affiliated with him. Hand loading and horse transportation methods were used with a primary and secondary breaker having a capacity of 200 to 300 tons per day. From 1899 to 1902 the quarry was called the "Cooke Stone & Ice Co.," and in 1902 it became a unit of the Connecticut Trap Rock Quarries.

In 1908 an 18- by 68-inch gyratory crusher as a primary breaker, with a 10- by 40-inch and two 7- by 28-inch gyratory crushers as secondary breakers, were installed and gave the plant a capacity of 800 tons a day.

In 1913 the name of the company was changed to the Connecticut Quarries Co. and in 1925 to the Connecticut Quarries Co., Inc. Mechanical loading and transportation were introduced in the spring of 1914, through the use of a 3/4-cubic yard steam shovel on wheels, two 3-ton gasoline locomotives on 36-inch gage track, and 4-yard dump cars. Drilling was done by steam-operated piston drills to a maximum depth of 22 feet.

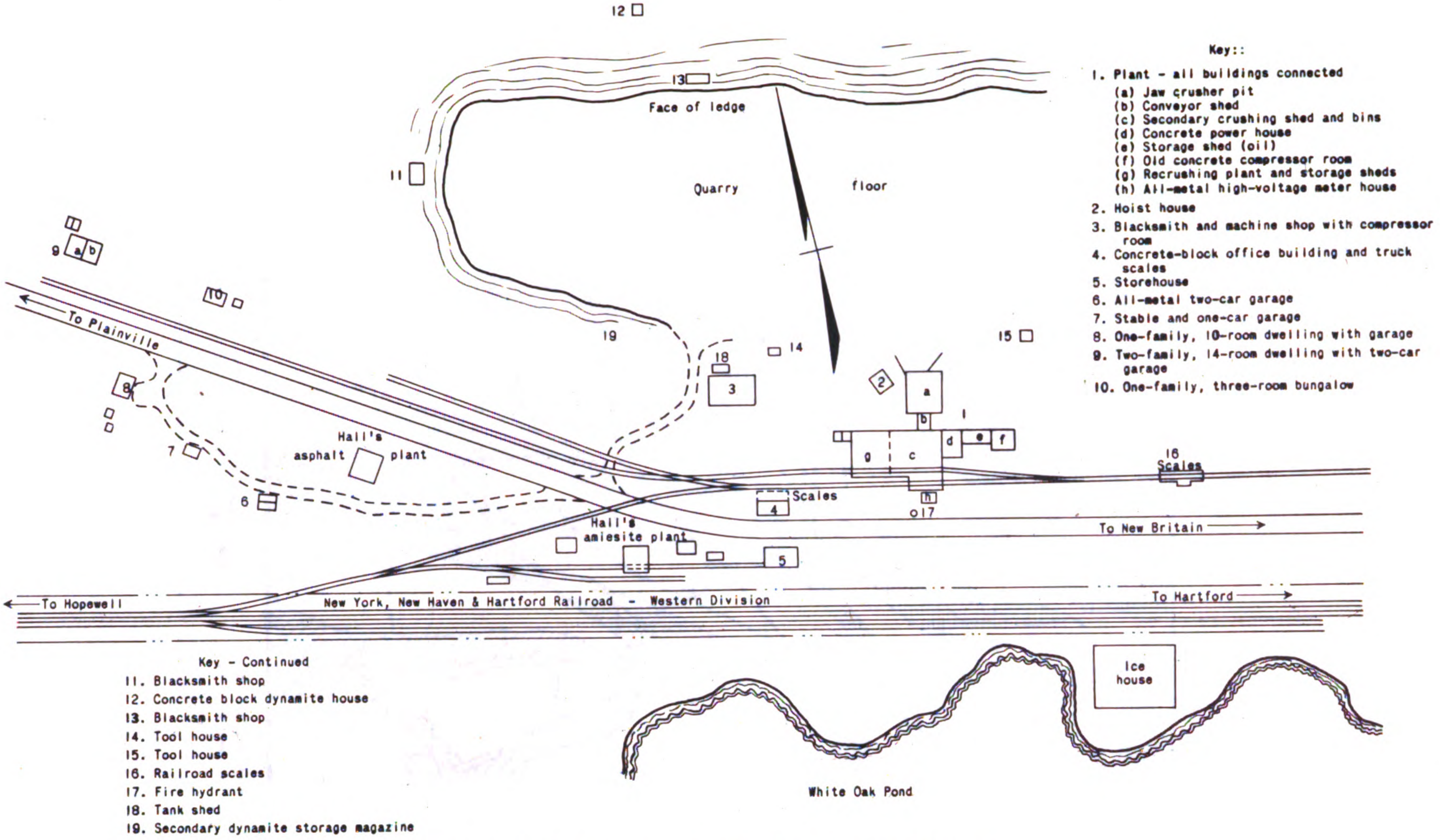
Electricity was first brought to the plant in 1916. Since that date, steam engines, drills, shovels, and hoists have been gradually replaced by electric motors, electric well drills, electric shovels, and electric hoists.

In 1920 a jaw crusher was added to the plant; later two 1 3/4-yard electric shovels, a fleet of fifteen 4-yard dump cars, and one 15- and one 18-ton steam locomotive were purchased. This new equipment increased the capacity of the quarry to 2,500 tons per day.

During the winter of 1928-29, the jaw crusher was relocated in order to replace an old bucket elevator with a modern 48-inch belt conveyor delivering stone from the primary to the secondary crusher.

In the spring of 1929 three 7 1/2-ton trucks eliminated the locomotive system in the quarry and greatly increased the haulage efficiency. This reduced the cost of transportation 3 cents per ton, secured a more efficient loading operation and a better balance between shovel and crusher, and thus created a very flexible quarry operation.

The installation in the fall of 1929 of a 5-foot cone crusher in place of the four secondary crushers and the addition in 1930 of one truck to the fleet increased the capacity of the plant to 3,000 tons per 10-hour day.



Key::

1. Plant - all buildings connected
   - (a) Jaw crusher pit
   - (b) Conveyor shed
   - (c) Secondary crushing shed and bins
   - (d) Concrete power house
   - (e) Storage shed (oil)
   - (f) Old concrete compressor room
   - (g) Recrushing plant and storage sheds
   - (h) All-metal high-voltage meter house
2. Hoist house
3. Blacksmith and machine shop with compressor room
4. Concrete-block office building and truck scales
5. Storehouse
6. All-metal two-car garage
7. Stable and one-car garage
8. One-family, 10-room dwelling with garage
9. Two-family, 14-room dwelling with two-car garage
10. One-family, three-room bungalow

Key - Continued

11. Blacksmith shop
12. Concrete block dynamite house
13. Blacksmith shop
14. Tool house
15. Tool house
16. Railroad scales
17. Fire hydrant
18. Tank shed
19. Secondary dynamite storage magazine

Figure 1.- Plan of quarry and plant, New Haven Trap Rock Co., Plainville, Conn.

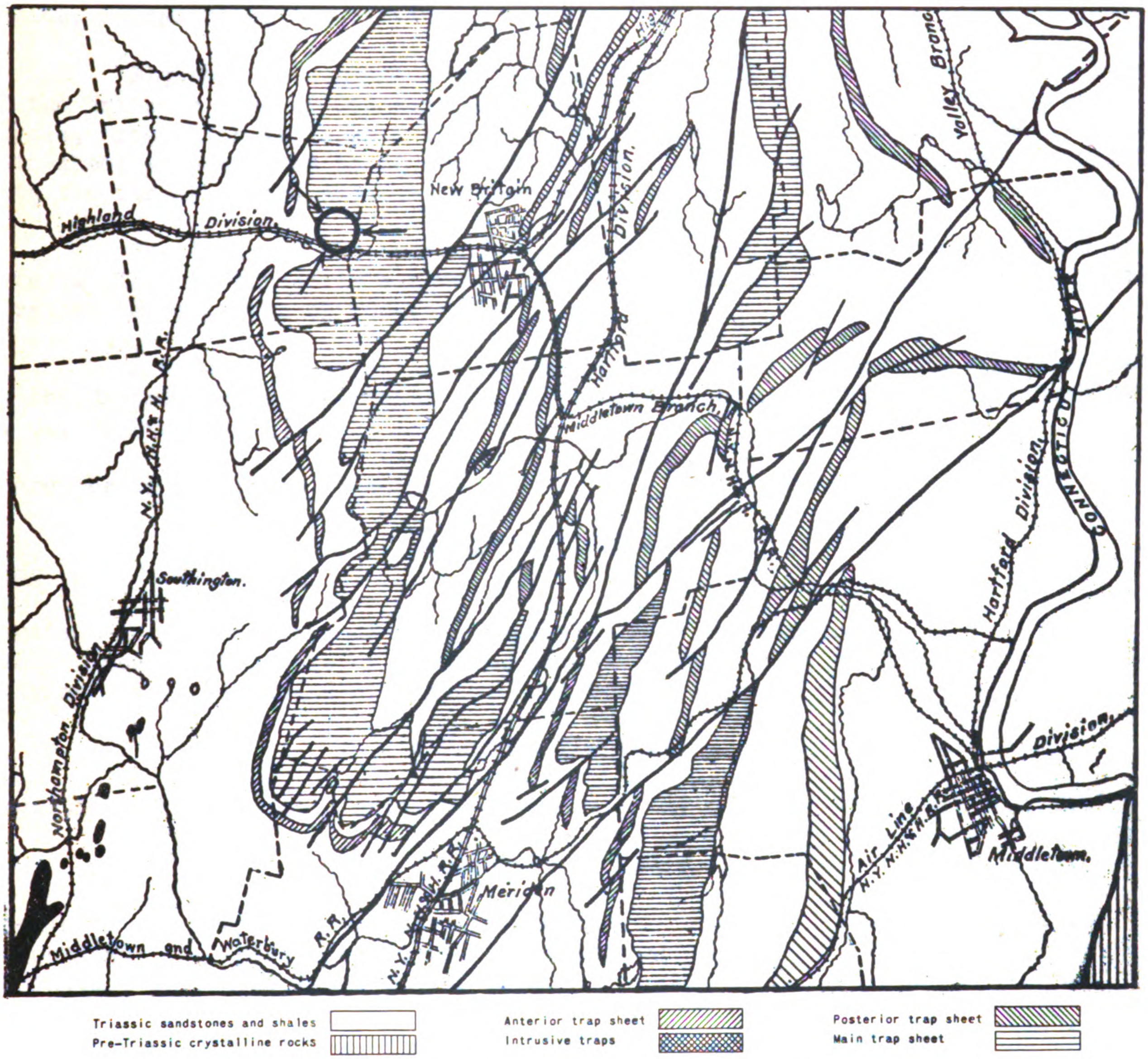


Figure 2.- Map showing trap sheets and faults in central part of Triassic area of Connecticut.

On April 1, 1935, the Connecticut Quarries Co., Inc., was consolidated with the former New Haven Trap Rock Co. into a new corporation known as New Haven Trap Rock Co.

GEOLOGY

The rock quarried at this plant is known as trap rock, which denotes vaguely a rather dark, basic, fine-grained, igneous rock consisting chiefly of augite, labradorite, and olivine.

Figure 2 is a map3/ showing trap sheets and faults in the central part of the Triassic area of Connecticut. The location of the plant is marked by a circle, from which it is seen that the quarry lies on the main trap sheet. This main sheet is estimated to be some 400 to 500 feet in depth and extends parallel with the strike of the adjacent sedimentary strata.

The depth of the overburden averages 4 or 5 feet but ranges from 0 to 9 feet. The overburden is a mixture of coarse loam and gravel on which there is a rather heavy growth of underbrush.

A mineral analysis of a representative sample of the rock, as prepared by the United States Department of Agriculture, Bureau of Public Roads, Washington D. C., on December 20, 1923 follows:

Character of material: Igneous rock   Name: Olivine   Diabase

Name		Percent
	ESSENTIAL MINERALS	
Augite	Silicate of lime, magnesia, iron and alumina	33.4
Plagioclase	Silicate of alumina, lime and soda	32.8
Olivine	Silicate of magnesia and iron	11.6
	ACCESSORY MINERALS	
Magnetite	Magnetic oxide of iron	2.6
	SECONDARY MINERALS	
Kaolin	Hydrous silicate of alumina	14.0
Serpentine	Hydrous silicate of magnesia and iron	5.6
Limonite	Hydrated oxide of iron	

Remarks: Specimen is a fine-grained, gray-black diabase composed essentially of kaolinized plagioclase (labradorite), augite, and serpentinized olivine.

3/ Portion of map by W. M. Davis in 18th Ann. Rept. of U. S. Geological Survey.

ESTIMATION OF TONNAGES

It is estimated that within the property boundaries and above the present quarry level are 27,000,000 tons of stone. At an average production of 300,000 tons a year the life of the quarry would be 90 years. Because the deposit is known to continue at least 400 feet in depth from the present cut, which is 135 feet high, the life of the quarry can be materially increased by starting a lower mining level.

PHYSICAL CHARACTERISTICS OF THE STONE

The rock at this quarry averages 186 pounds per cubic foot in the solid and has a crushing strength of 49,400 pounds per square inch, as given by the United States Government's test of trap rock. The Deval abrasion test gives a French coefficient of wear of 25. The nonporous nature of this rock is shown by the fact that its water absorption is only 0.12 pound per cubic foot.

The fissures or joints in the main trap sheet are quite pronounced, but they are spaced so irregularly and far apart that the stone breaks into very large pieces on the primary blast. This poor fragmentation results in high secondary drilling and blasting costs, therefore tunnelling was abandoned and well drilling adopted as the most satisfactory method of primary blasting.

MINING METHODS

Stripping

The overburden is usually removed either in the late fall or early spring because at this time the necessary company men and equipment are available. Stripping is accomplished by a 3/4-yard steam shovel on caterpillars, loading into two 4-yard trucks equipped with pneumatic tires[4]. From 9,000 to 10,000 cubic yards are removed each year at a rate of about 200 to 250 cubic yards a day.

For the past few years the overburden has been used for fill on a new road to the top of the ledge. It is expected that in the future this overburden will be sold as fill to the neighboring city and town.

The crew for stripping usually consists of a shovel runner, shovel fireman, clean-up man, and two truck drivers. While the new road was being graded a man was also required at the dump.

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[4] This shovel has since been replaced by a gasoline-powered unit, thus eliminating the expense of a fireman, maintenance of water lines, etc.

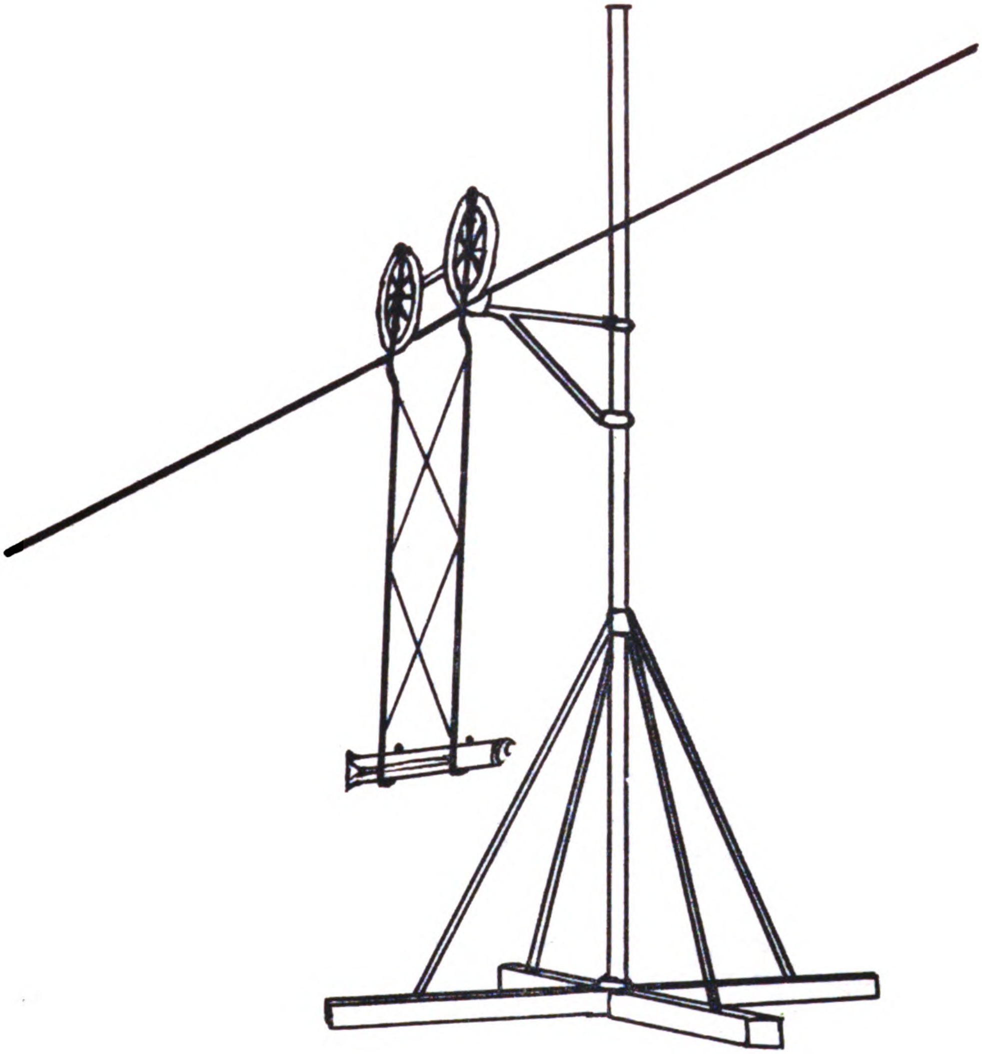

Figure 3.- Drill-bit cableway.

PLAINVILLE STRIPPING COSTS

Period covered: Sept. 23 to Dec. 10, 1930. Yardage (estimated): 8,907 cu.yd.
number of loads: 2,252

Items	Cost	Cost per cu. yd.
Coal	$288.00	$0.0324
Shovel engineer	397.18	.0445
Fireman	214.80	.0241
Pitman	204.79	.0230
Dumpman	171.95	.0193
Trucking	841.86	.0945
Repairs (estimated)	111.30	.0125
Total	2,229.88	0.2503

The average load was 3.96 cubic yards. Between 9,000 and 10,000 cubic yards were removed per year. From measurements on map, an area of 48,000 square feet was uncovered. The volume removed was 8,907 cubic yards or 240,500 cubic feet. Thus the average depth equals 240,500 divided by 48,000 or 5 feet.

Primary Drilling

Two traction-type well drills equipped with 15-hp. electric motors are used for primary drilling. This type of drilling was chosen as a result of study of the physical characteristics of the ledge and past experience in the comparative breaking effect of several methods of drilling and blasting.

Six-inch drill bits are used on a 4 1/4-inch by 20-foot stem with no casing. Holes are drilled at an average rate of 5 1/2 feet per 9-hour day. They are spaced about 17 feet apart, have a 22-foot burden, and are sunk to a depth of 130 to 150 feet.

The drilling crew consists of two drillers, one blacksmith, and one foreman. Bits are transported to and from the site by an ingenious overhead cableway, designed and built by the well drill foreman. (See fig. 3). This eliminates the use of one man to transport the drill bits.

An account of the hardness of the rock bits are changed about every hour. In order to keep both drills busy the blacksmith must dress about 16 bits per day.

WELL-DRILLING COSTS

Period: 227 working days in 1930 Drilling: 1,217 feet

Description	Amount	Cost per foot
Foreman	$944.86	$0.776
Driller	1237.40	1.017
Blacksmith	678.43	.557
Electric power[1]	137.97	.114
Cable expense	55.00	.045
Repairs and miscellaneous[1]	175.00	.144
Depreciation	240.50	.198
Interest on investment	143.80	.118
Total	3,612.96	2.969

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[1] Estimated.

The approximate ratio of cost per foot to cost per ton extracted is 1 to 54.

SECONDARY DRILLING

At present five 59-pound jackhammers using 1-inch hexagonal steel and one drifter using 1 1/4-inch round steel are used for secondary drilling at this quarry.

Some 200 to 250 feet of holes are drilled each day. The 59-pound jackhammers have been found to drill 3.56 inches per minute of actual cutting time. Some experiments have been performed on a 62-pound jackhammer, and this type, owing to its slower rotation and harder hitting, has been found more satisfactory for the hard rock. On a comparative basis it has been found to drill 5.33 inches per minute. It is therefore expected that as the 59-pound drills wear out they will be replaced by the heavier type.

The average run for drill bits is from 12 to 18 inches. The blacksmith, with one helper, sharpens from 150 to 200 drills a day.

The location, depth, and number of holes drilled in the rocks on the quarry floor are determined by the quarry foreman.

Primary Blasting

Because of vibration due to heavy blasting, only four or five holes can be shot at one time without causing complaint from the neighboring town of Plainville or the city of New Britain. When complaints are received, pin seismographs are set up at that location at the time of the next blast to determine the extent of the vibrations. Most of these complaints are not justified, but use of the pins is helpful in convincing people that the resulting vibrations are not serious.

When the burden at the toe is more than 25 feet, the holes are sprung before loading. This is accomplished by a 100-pound charge of 60 percent gelatin - dynamite in 5- by 16-inch sticks tamped with dirt and water and ignited by 3-minute fuses. This springing provides space for an additional charge of dynamite at the bottom sufficient to break out the toe.

The dynamite is transported to the top of the ledge by motor truck. A shipping schedule is usually arranged so that the dynamite can be taken directly from the freight car to the holes for immediate loading. The excess dynamite is stored in a magazine near the quarry.

A crew of five men load the well drill holes under the supervision of the quarry foreman. Four holes are loaded at a time. One man transports the dynamite to the holes, and one man is stationed at each hole to cut and drop the dynamite in the holes. The 5- by 16-inch cartridges are slit to insure more complete filling of the holes. The foreman carefully supervises the loading operations and takes frequent measurements of depth to make certain that no air pockets or voids occur in the explosive charges.

If a charge of dynamite becomes lodged part way down, a long, pointed 2- by 4-inch timber attached to a rope is dropped down to break up the charge. Heavy lead weights also are occasionally worked up and down to dislodge the stick of dynamite.

Before loading, cordeau is strung the entire depth of each hole. An exploder is attached at the bottom of the cordeau as a safety measure to insure the bottom charge igniting and thus prevent any chance of the toe not breaking.

Some 500 to 750 pounds of 75 percent gelatin dynamite is first loaded in the bottom of the hole. Then approximately 500 pounds of 60 percent dynamite is dropped in, and the top charge is made up of nearly 500 pounds of 60 percent extra dynamite. If the hole becomes enlarged during drilling, a little fill is inserted between charges. The rest of the hole is then tamped with screenings or sifted dirt.

The cordeau from each hole is spliced to the trunk or main cordeau, which is ignited by an electric detonator. The foreman and crew of five men complete the loading of four holes in 5 to 6 hours.

About 1,500 pounds of dynamite is used in each hole and, with end break, approximately 4 3/4 tons of rock are recovered per pound of dynamite. About 50 to 55 tons of rock are obtained per foot of hole drilled.

Secondary Blasting

Secondary blasting on the quarry floor is done by a blaster with one helper, using 1 1/4- by 8-inch 60 percent extra dynamite. The average charge is one-half cartridge per hole. The amount of dynamite used depends largely on the characteristics of the rock.

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As the quarry is located along a main highway, traffic is stopped about 5 minutes before all primary and secondary blasts.

The blaster places a 3-minute fuse, blasting cap, and cartridge in each hole, and his helper tamps each hole with screenings. The secondary blasts are set off by the blaster and a helper at the noon hour and, if necessary, directly after closing time.

Loading Stone for the Crusher

Two electric shovels equipped with 1 3/4-yard dippers are used for loading. One of these shovels is mounted on caterpillars and the other on crawling traction trucks. They are equipped with 75-hp. motor generator sets, a 28-foot boom with 17-foot dipper handles, and standard electric dipper trip complete.

Each shovel handles an average of 102 tons of stone per hour. A truck is loaded by four or five passes of the dipper in a lapsed time of 1.8 to 2 minutes. Under the best operating conditions each shovel will move 140 to 160 tons an hour.

Two men, an operator and a pitman, constitute a shovel crew. An extra man, alternating as oiler and pitman, sometimes works between both shovels when conditions warrant it.

Power is brought to the shovels by No. 0125 stranded, rubber-covered flexible cable from one of three junction boxes located at convenient points in the quarry. Formerly voltage regulation was poor at the shovels; this poor regulation was overcome by increasing the feed cable to the present size and increasing the size of the main-line wires from the transformers to the quarry junction boxes.

Transportation

Four 7 1/2-ton trucks equipped with 8-cubic yard, end-dump, steel bodies, as shown in figure 4, are used to transport stone from the shovel to the crusher. This type of transportation has been found to be much more flexible and economical than the track system used until 1929.

Each truck is equipped with a hydraulic hoist, and the bodies are designed to operate the self-dumping tailboard as the load is being dumped. These trucks require only 0.7 to 0.9 minute in dumping and make a round trip averaging 1,560 feet in approximately 5 1/2 minutes. There is a slight upgrade at the dump.

The truck drivers have no prescribed circuit. They are free to use their own judgment as to which of the two shovels they should serve on their return trip. Occasionally, when the bins are full, a truck from the quarry hauls stone from the bins to the storage piles.

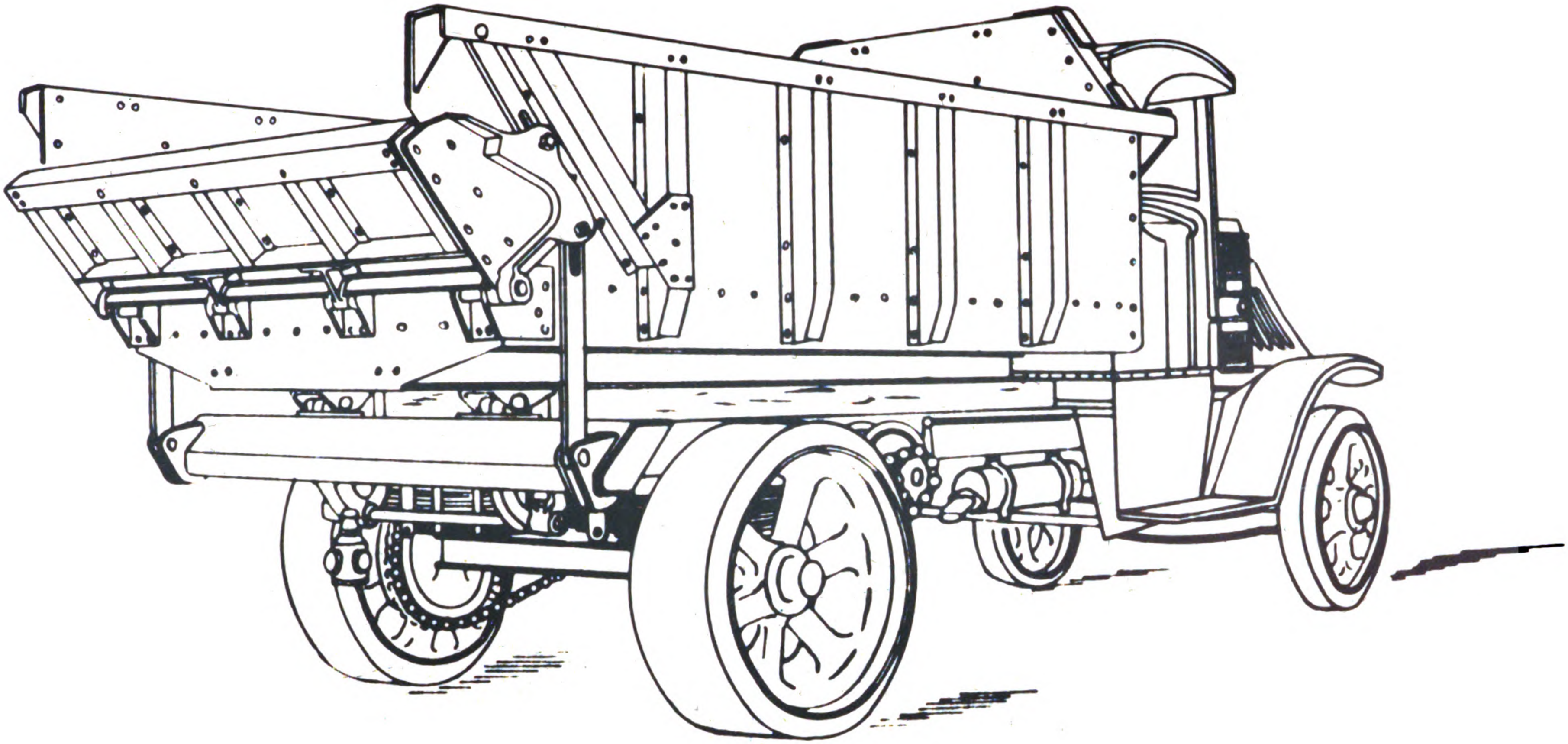

Figure 4.- Self-dumping quarry truck.

On full schedule these four trucks total about 330 trips a day. Solid "plain profile" and "subway special" tires are used on the trucks, and they have been found to give the most satisfactory service. A summary of transportation costs follows:

Plainville no. 4, Average cost per truck

(Four trucks hauling 250,540 tons, 1931)

Interest and depreciation	$1,600.00
Cost of driver	668.25
Cost of gasoline	258.93
Cost of oil	39.41
Maintenance and repairs	593.30
Rear tires	212.00
Front tires	102.00
	3,473.89

Average hours per day	8.9
Number of working days	150
Mileage	4,424
Tonnage (including storage)	62,635
Number of trips	8,135
Miles per trip	.544
Average tonnage per trip	7.7
Number of working days at 10 hours per day	133.5
Average cost of gasoline, per gallon	.09
Average cost of oil, per gallon	.4675
Total cost per ton hauled	.055

Trucks in operation 3 years

Two-year truck operation comparisons

	Cost per 10-hour day		Cost per mile		Cost per ton	
	Middle-field quarry[1]	Plain-ville quarry[2]	Middle-field quarry	Plain-ville quarry	Middle-field quarry	Plain-ville quarry
Interest and depreciation	[3] $4.39 [4] 9.64	$4.39 10.71	$0.492	$0.306	$0.0153	$0.0188
Driver........	5.17	6.00	.264	.171	.0082	.0105
Gasoline......	2.57	2.18	.131	.062	.0041	.0039
Oil...........	.43	.33	.022	.009	.0007	.0006
Maintenance and repairs.	2.87	5.50	.147	.157	.0046	.0096
Rear tires....	1.50	2.25	.077	.064	.0024	.0039
Front tires...	.33	.78	.017	.022	.0005	.0014
Total......	[3] 17.26 [4] 22.51	21.43 27.75	1.150	.791	.0358	.0487

[1] Average round-trip haul, 1,400 feet
[2] Average round-trip haul, 1,560 feet
[3] Depreciation based upon 365 days.
[4] Depreciation based upon actual number of working days.

42- by 54-inch Jaw Crusher-A[6]

Figure 5 is a flow sheet of the crushing plant.

The stone from the quarry is first broken in a 42- by 54-inch jaw crusher, running 160 r.p.m., with the jaws set 6 1/2 to 7 inches at the discharge. At this setting the crusher has a capacity of 250 to 300 tons per hour. The top bearing of the pitman is water-jacketed, and the crusher is equipped with a safety toggle. The crusher is lubricated by six extra-large, special-compression, grease cups, each holding approximately 10 pounds of grease. The bearings are lubricated both at the top and bottom.

The crusher is driven by a 22-inch, "endless," 7-ply, 35-ounce, silver duck belt on 24-foot centers by a 150-hp., 600-r.p.m., slip-ring induction motor equipped with spherical-type bearings (2). [7]

The manganese-steel, swing-jaw plates are made in two sections and may be turned end to end to prolong their life, which is normally about 900,000 tons. The fixed jaw plates are now made 6 inches thick and will outlast the swing-jaw plates provided no cracks develop.

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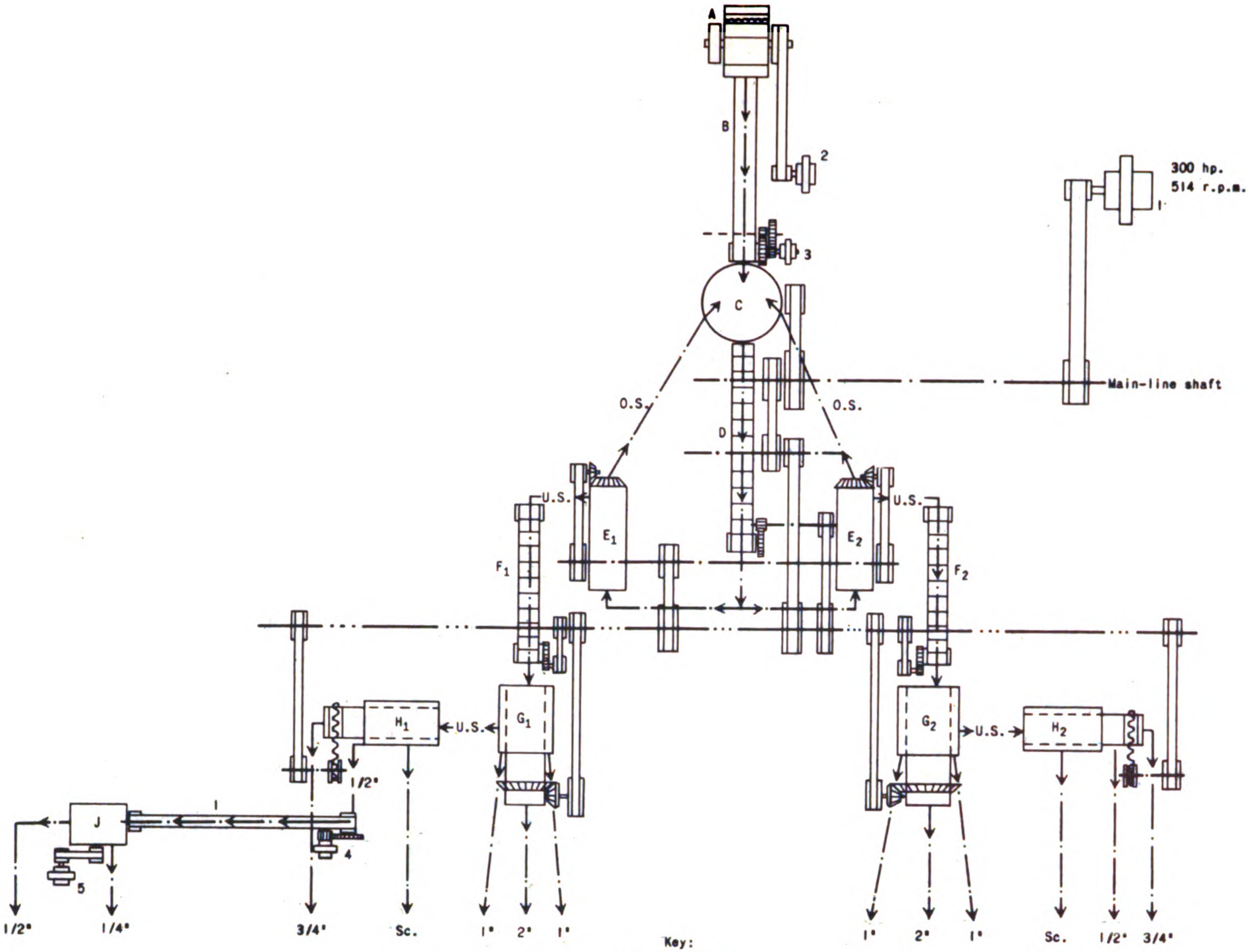
[6] Letters refer to flow sheet, figure 5.
[7] Figures in parentheses refer to flow sheet, figure 5.



Key:
O.S. - Oversize
U.S. - Undersize
Letters refer to text

Figure 5.- Flow sheet of crushing plant.

Blocks in the crusher are handled by a large hook fastened to a 5/8-inch cable run from a 10-ton steel derrick equipped with an electric hoist. This derrick is also used to handle heavy equipment during plant repairs and is so located that it will reach both the jaw and secondary crushers.

48-inch Belt Conveyor B

Material is conveyed from the primary to the secondary crusher by a 48-inch belt conveyor, 39 feet center to center and inclined at an angle of 19-1/2° to the horizontal. It handles rock up to 11 inches in diameter at a rate of 400 to 500 tons per hour, is loaded intermittently and runs at a speed of 300 feet per minute.

The conveyor when first installed was run at a speed of 250 feet per minute, but it was speeded up to more nearly equal the speed of travel of the rock at the feed point. This substantially reduced the wear on the belt.

The conveyor is equipped with three-pulley troughing idlers with roller bearings and with four extra-heavy idlers at the feed point. A head pulley 36 inches in diameter and a tail pulley 30 inches in diameter are used.

The idlers are mounted on 12-inch channel-steel stringers with 1/8-inch plate decking, and the entire conveyor is supported on structural steel.

A 20-hp. motor running at 900 r.p.m. is used to drive the conveyor through two gear reductions (3). The motor is equipped with an extended shaft on which is mounted a solenoid brake to prevent reversal of the conveyor in the event of a break-down.

The conveyor was first equipped with a 7-ply, 20-ounce-duck, 48-inch belt with 3/16-inch top cover by 1/16-inch pulley cover. This belt did not last out the season and was replaced by a 48-inch, 7-ply, 28-ounce-duck belt with 1/4-inch top cover by 1/32-inch pulley cover. The latter belt lasted more than two seasons and was replaced in March 1932 by a 48-inch, 6-ply, 28-ounce-duck belt with a 1/2-inch breaker strip in the center which still appears to be in good condition. It is estimated that this belt will handle some 750,000 tons, which is satisfactory when the short centers are considered.

5 1/2-foot Cone Crusher, C

All secondary crushing is done by a 5 1/2-foot cone crusher equipped with a coarse crushing bowl. This gives a feed opening of 9 3/4 inches, and the discharge opening is set at 1 1/4 inches to 1 5/8 inches, depending on the relative demand for smaller and larger sizes. This self-feeding crusher at 510 r.p.m. has a capacity of approximately 350 tons an hour.

The crusher is belt-driven from a 65- by 22-inch pulley on the main-line shaft of the plant to a 42- by 22-inch pulley on the crusher, using 56 feet of 20-inch by 9-ply, "raw-edge" transmission belt. The belt runs approximately 5,350 feet per minute, and because of this excessive speed the normal life is only 3 to 4 years.

42-inch Bucket Elevator, D

The stone is delivered from the cone crusher to the scalping screens by a 42-inch, roller-chain bucket elevator running on 48-inch pitch-diameter sprockets. There are 66 buckets in the elevator; it operates on 60-foot centers and is belt-and-gear driven from the top bin countershaft.

This elevator runs about 107 feet per minute, which gives it a capacit of about 350 tons per hour at 50 percent of bucket capacity. The buckets are 42 inches long, 19 inches across the top, and about 21 inches deep. At intervals the elevator buckets run completely full and show a momentary load of 600 to 700 tons per hour. The elevator is supported on a wooden framework and is inclined at an angle of approximately 73 1/2° to the horizontal. At normal capacity it requires 45 hp.

24-inch Bucket Elevators, F1-F2

All the undersize from the scalping screens E and E2 is elevated to the screens G1 and G2 by two similar 24-inch, continuous-bucket, belt elevators. Each elevator is made up of 63 buckets; each bucket is 24 inches long by 12 1/4 inches deep by 10 1/2 inches wide across the top and runs on approximately 32-foot centers at a rate of 250 feet per minute.

At this high speed each elevator has a capacity of 350 tons an hour at the usual bucket level, and since it occasionally runs completely full there is known to be a circulating load which at times is nearly equal to normal plant run.

These elevators each require approximately 15 hp. and are belt-and-gear driven from the top-bin countershaft.

Sizing

All the principal sizing of the stone is accomplished by the use of trommel screens, as shown in the following table:

Screen analysis

No.	Type	Diameter by length, feet	Jacket diameter by length, feet	Size of opening, inches	Jacket-size of opening, inches	Screens, tons handled per hour	Jacket, tons handled per hour	Slope inches per foot	R. p. m.
E1	Trommel	5 x 15		2 1/4 x 2 1/4		175		2	17
E2	do	5 x 15		2 5/8 x 2 5/8		175		2	17
G1	do	4 x 15	5 1/2 x 10	1 3/8 x 1 3/8	1 x 1	150	68	1 1/2	15.5
G2	do	4 x 15	5 1/2 x 10	1 3/8 x 1 3/8	7/8 x 7/8	150	68	1 1/2	15.5
H1	do	4 x 12	5 x 10 1/2	5/8 x 5/8	2/ 6	31	16	1 1/2	13.5
H2	do	4 x 12	5 x 10 1/2	1/ 5/8	3/8 x 3/8	31	16	1 1/2	13.5
J	Vibrating	3 x 5	5/16 x 5/16			11		25°	1250

1/ Diameter
2/ Mesh

In recent years improvements have been made in quarrying and crushing the stone, thus the capacity of the plant is increased without any change in the screening equipment. At present these screens are running to full capacity, and any further increase in plant capacity will necessitate new screening equipment.

Occasionally 1/4-inch stone is required for a special market, and this is produced by passing the 1/2-inch stone from the jacket of screen H1 and H2 over a 3- by 5-foot vibrating screen driven by a 1-hp., 1,800-r.p.m. motor. The material is conveyed to this screen by a 17-inch belt conveyor running on 16-foot centers and driven by a 3-hp., 1,130-r.p.m. motor.

Manganese-steel, woven-wire screen sections are used on practically all screens, as they have been found to give a greater screening capacity per square foot of screen area and to be more efficient. Scalping screen sections with 2-inch, 1-inch, and 3/4-inch openings ordinarily last 6 years. Manganese sections on the 1/2-inch screen usually are not replaced until after 7 or 8 years of service.

With the average crusher setting the various sizes of stone are produc in the following proportions:

Commercial Size, inches	Percent	Through (inches)	Retained on (inches)
2	55	2 5/8 sq.	1 3/8 sq.
1 1/4	25	1 3/8 sq.	7/8 sq.
3/4	10	7/8 sq.	5/8 sq.
1/2	7	5/8 sq.	3/8 sq. and 4 1/2 mesh
Screenings...	3	4 1/2 mesh	

Recrushing

Whenever the market requires an excess of 3/4- and 1/2-inch sizes of stone and the 2- and 1-inch storage piles are filled to capacity, the recrushing plant shown in figure 6 is operated. Either 2- or 1-inch stone, or both, may be taken by truck from the storage piles and discharged by a ramp into the recrushing plant.

Plant supplies

(Plainville No. 4, 1929)

	Amount used, gallons	Cost	Cost per ton of stone
Coal	[1] 73.285	$572.91	$0.0021
Gasoline	14,111	1,834.43	.0066
Fuel oil................	4,586 1/2	412.78	.0015
Diesel oil..............	635 1/2	324.10	.0012
Cylinder and engine oil.	927	299.43	.0011
Crusher oil.............	1,234	303.33	.0011
Compressor oil..........	246 1/2	103.53	.0004
Black oil...............	612 1/2	61.25	.0002
Grease..................	[2] 4,379	262.74	.0009
Total oil and grease.		1,767.16	.0064

[1] Tons.
[2] Pounds.

Bin Storage

The storage bins, which are constructed of wood, have a total capacity of 820 tons of stone. Figure 7 shows the arrangement and capacities of the various sizes.

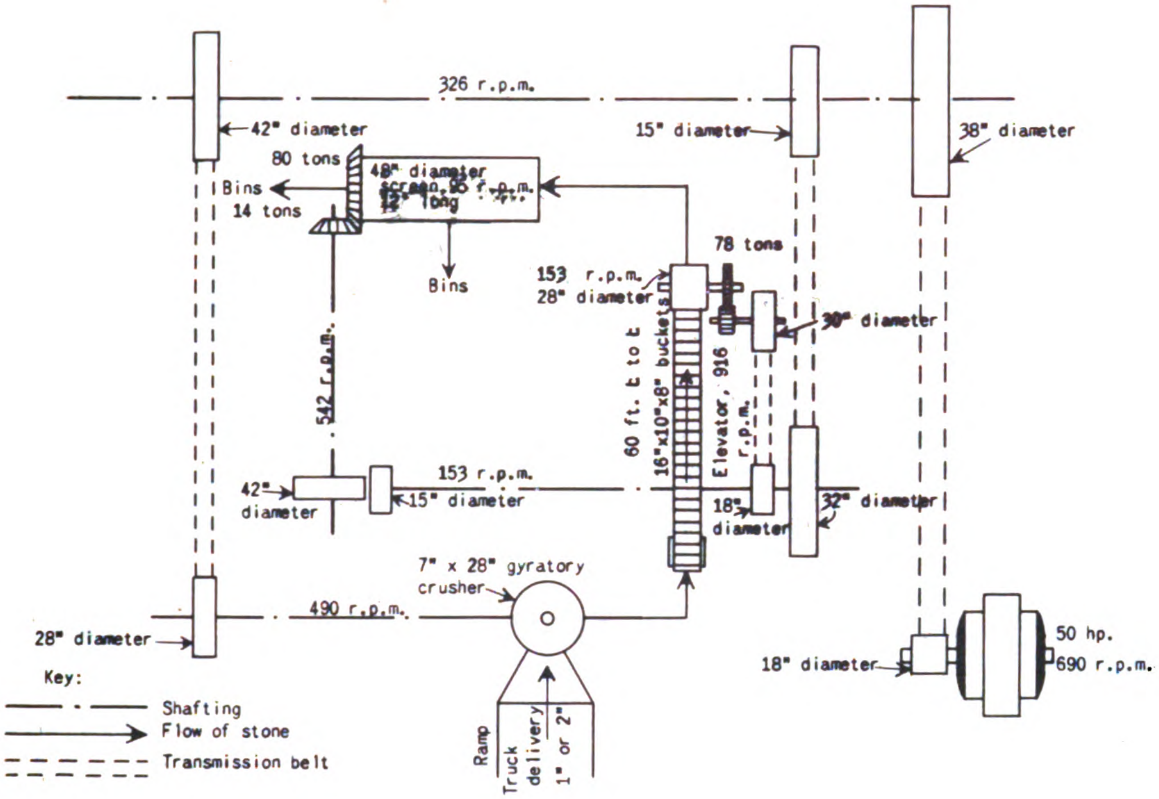


Figure 6.- Recrushing plant, flow diagram and power transmission.

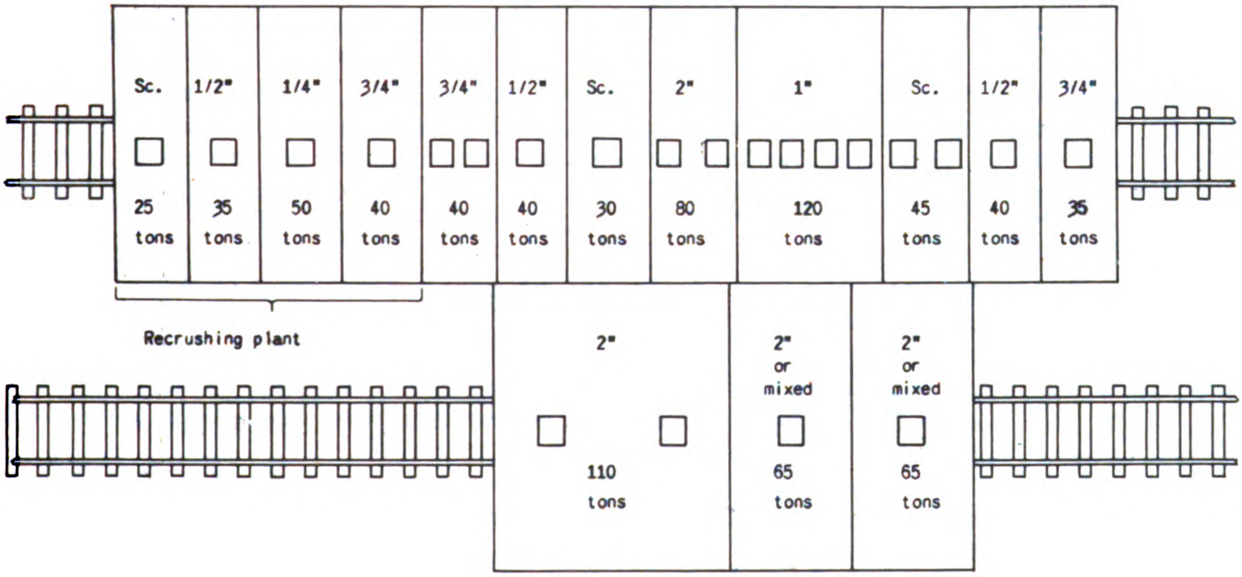


Figure 7.- Storage bins at plant no. 4, total bin capacity 820 tons. (Capacities shown are free-flowing capacities; denotes chute gate.)

There is a spur track under each bin so that any or all of the contents may be emptied into railroad cars. Trucks are loaded in the same manner as railroad cars, and the arrangement of the bins is such as to make it possible to load any size of stone required by trucks, while the "battleships" or low-side cars are being loaded.

Ground Storage

There is space for some 75,000 tons in ground storage, of which approximately 35,000 tons may be stored directly along the railroad siding.

A clamshell crane mounted on caterpillars handles all shipments from ground storage. A No. 2 gasoline crane is equipped with a 1 1/4-cubic yard clamshell bucket, 3/4-cab, and a 40-foot boom. This crane will load a 60-ton battleship car in 40 minutes, including the time required to maneuver the cars. When this machine runs continually it uses about 40 gallons of gasoline per 9-hour day.

When it is necessary to make a rail shipment from a storage pile that is not situated along the railroad siding, trucks are first loaded by the clamshell and the load dumped into the railroad cars by a ramp. Ordinarily, only truck shipments are made from such storage piles, but occassionally it is necessary to resort to them for rail shipments when the railroad storage is depleted.

Shipments

Orders for shipments are received by the plant clerk from the main office in New Haven by telephone early in the morning and confirmed by mail the same day. The clerk then notifies the superintendent of these orders so that he may plan his production for the day. Instructions are then given the car loader as to the number of cars and the size and amount of stone to be loaded.

The company's siding has room for 32 battleship cars and 10 gondolas or low-sides. This side track is on an incline so that the cars may be spotted by gravity under the bins, onto the 100-ton scales, and down to the end of the track to await the train. If a car must be pulled back up the track, it is towed by one of the company's trucks.

The car loader reports to the clerk on a slip of paper the gross weight, car number, and size of stone of each car loaded. The clerk keeps a record of the car numbers, and tare weights of all empties received, and refers to this to make out the bills of lading for shipments. The cars are checked as to number, size, and destination as they are being pulled out.

All truck loads are weighed on the 40,000-pound scales adjoining the office building. Tickets are made out in triplicate by the clerk for each truck load, showing the account to be charged, destination, trucker, size, gross, tare, and net weight.

A report of every car and truck load of stone shipped is made at the close of each day sent to the main office. On a record day this plant has sent out some 1,500 tons of stone entirely by trucks, in addition to the usual rail shipments; at times it has shipped as many as 48 cars totaling about 2,800 tons in 1 day. During the busy season the plant averages 500 tons in truck loads and 1,300 tons in rail shipments per day.

Blacksmith Shop

The blacksmith shop is a hollow-tile, concrete, one and one-half story building with a metal roof and a floor area of approximately 1,600 square feet. The shop is partitioned off to give one-half the available space to the blacksmith shop, three-eights to a machine shop, and one-eighth to the compressor room.

The compressor room contains an 18- by 11- by 14-inch angle compound compressor rated at 1,051 cubic feet of free air per minute at 100 pounds pressure. This compressor requires 166 hp. when operated at 86 percent of its rated capacity. The machine is direct-connected to a 174-hp. synchronous motor running at 257 r.p.m., which is excited by a 3 1/2-kw, 125-vole, direct-current generator running at 115 r.p.m. Air is pumped into a 4- by 10 1/2-foot receiver approved for 125 pounds pressure, from which a 4-inch line carries the air 350 feet to the center of the quarry where it terminates in a 3-inch line paralleling the quarry face for 250 feet each way from the 4-inch line. Plugs are provided in the 3-inch line from which 1-inch pipe lines feed air to the quarry drills. The compressor also supplies air to the drill sharpener and oil furnace.

Water is pumped by an air lift from a 155-foot well located just outside of the shop at the rate of 100 gallons per minute to a 5,000-gallon tank. This furnishes cooling water for the compressor and jaw crusher.

The machine shop contains a power-drill press, power hack saw, a bolt-threading machine, and a motor-driven bench grinder.

The blacksmith shop is equipped with an oil furnace and a drill sharpener having an automatic centering device. It also contains an open forge, an anvil, and all tools associated with this type of shop.

Storeroom

The storeroom is a one and one-half story, wood-frame building in which are kept the usual repair parts necessary for the shovels, crushers, screens, etc. Additional material is obtained by a requisition to the main office through which all principal buying is done. All requisitions for material must be approved by the general manager before being ordered.

In an emergency, material may be obtained by plant order on the signature of the superintendent. A copy of this order is sent to the main office to be used as a check against invoices received.

POWER

The electric power for this plant is purchased from the Connecticut Light & Power Co. and metered on the secondary side of its transformers. The monthly bill is figured as the sum of the energy and demand charges, and there is a minimum demand based on 60 percent of the kilowatt load specified in the contract.

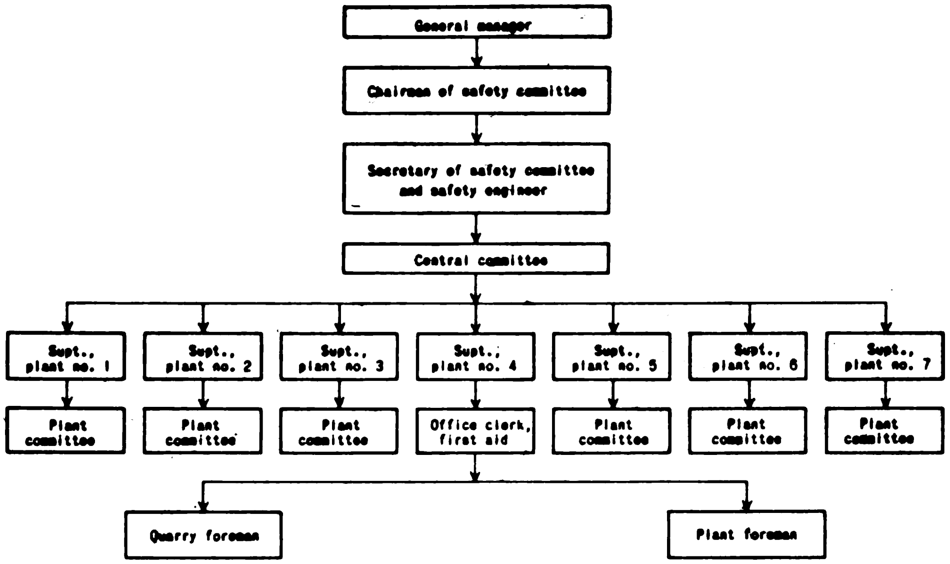


Figure 8.- New Haven Trap Rock Co., safety organization.

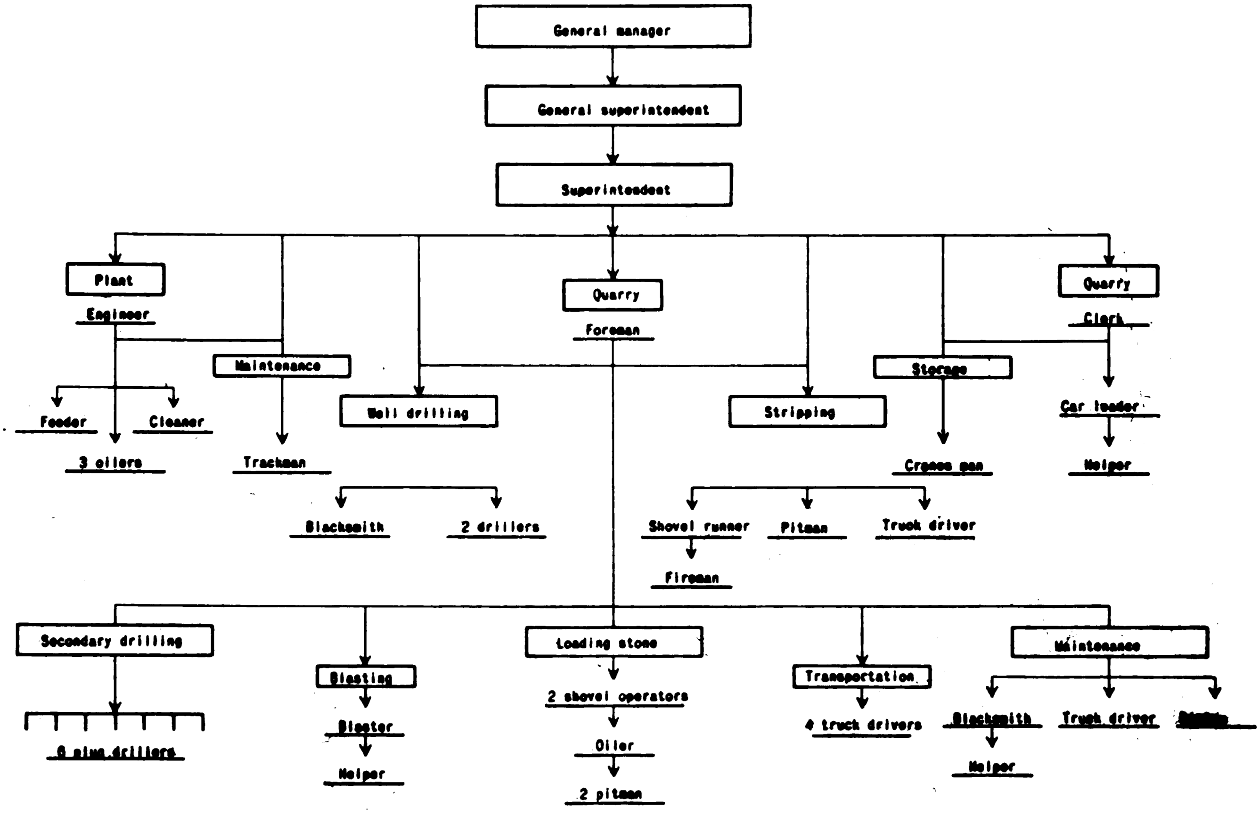


Figure 9.- New Haven Trap Rock Co., plant organization.

From the transformers the circuit is divided, one circuit feeding the quarry-shovel junction boxes and the other going to the plant switchboard. From this point feed lines for the compressor, well drills, hoist motor, etc., are taken, all of the circuits being strung overhead.

This plant is equipped with a control device recording demand to eliminate abnormal fluctuations in the load and so reduce the demand charge. Whenever the kilowatt demand during any 15-minute period goes above a predetermined normal value, an alarm is automatically sounded through a relay and all operations on the shovels, drills, etc., are immediately ceased for the remainder of that period. These abnormal fluctuations do not occur often enough to affect seriously the production but are of such magnitude as to affect considerably the power bill.

The total cost of power at this plant averages approximately $0.0221 per kilowatt-hour, and some 2.72 kw.-hr. of energy are required to produce 1 ton of stone.

Power analysis, 1929

(Tonnage, 276,574)

	Rated, kw.-hr.	Kw.-hr consumed, 67.3 percent of rated	Cost	Cost per ton	Kw.-hr. per ton
Plant..............	642,481	431,105	$9,108.49	$0.0329	1.56
Shovels............	211,797	206,561	4,565.50	.0165	.75
Well drills........	41,007	27,516	581.41	.0021	.10
Compressor.........	119,624	80,268	1,696.06	.0062	.29
Miscellaneous hoist, pumps, etc.......	10,000	6,710	141.78	.0005	.02
Total...........	1,024,909	752,160	16,093.24	0.0582	2.72

SAFETY ORGANIZATION

The safety organization of the company is made up of the plant committees, central committee, and safety committee. The chairman and secretary of the safety committee are appointed by the general manager. The rest of the safety committee is made up of the superintendents of the various plants, who comprise the central committee. The safety organization is shown graphically in figure 8.

The plant committees vary at the different quarries, depending on the size of the quarry and the number of men employed. Each superintendent is allowed to choose his own plant committee, which ranges in size from one to four or five men. Many of the employees of the organization are first-aid-trained. One class comprised the superintendents, clerks, and foremen of the various plants and was instructed under the direction of United States Bureau of Mines first-aid instructors. Classes were then formed at each plant in which the superintendents, etc., served as instructors, and the classes were examined by an instructor from the Bureau of Mines.

A report of every accident is made by the quarry clerk and sent to the main office. These reports are read by the secretary of the safety committee at the subsequent meeting of the Association of Superintendents and voted "avoidable" or "unavoidable" by the committee. If an accident is found to be due to the individual's own carelessness, he is written a letter of censure by the secretary.

The accident record of the Plainville quarry for the past few years is as follows:

Year	Frequency rate	Severity rate	Man-hours
1929	81.162	1.56	123,211
1930	44.286	.469	112,909
1931	11.6	7.0	85,093
1932	0	0	44,123
1933	21.066	.295	47,469
1934	0	0	56,862
1935	0	0	45,079

This company is a member of the National Safety Council, and monthly posters for bulletin boards are obtained through them.

EMPLOYEE PAY SYSTEM

The employees at the plants are all paid on an hourly basis. The superintendent, assistant, and clerk receive a guaranteed weekly rate for 9 hours a day, 6 days a week. Overtime work is paid at the regular hourly rate, and no bonuses are in effect.

The wage scale for direct labor ranges from 40 cents to $1.00 an hour, and averages $0.6536 per hour.

In a normal year the plant averages some 115,000 man-hours of labor and 9 1/2 hours per man per day. The plant is in operation approximately 200 full days of the year.

Distribution of authority is shown in figure 9.

ASSOCIATION OF SUPERINTENDENTS

Once a month the keymen of the company gather at some central point to hold a dinner and meeting. The general superintendent proposed these meetings and the superintendents started them in 1927 under the name of the "Association of Superintendents of the Connecticut Quarries Co., Inc." Membership now includes the general manager, vice president of administration, treasurer, sales managers and salesmen, office manager, bookkeeper, and safety engineers besides the superintendents and assistants at the various quarries and distributing bins. The organization is now known as the Association of Superintendents of the New Haven Trap Rock Co.

The association has for its object "to create a spirit of social relationship, harmony, and cooperation, with educational features pertaining to the trap-rock industry that are so seemingly necessary to make for real progressiveness and mutual understanding." Part of the expense of running this association is paid by the company and the remainder in dues.

After dinner the order of business is as follows:

1. Roll call
2. Reading minutes of last meeting
3. Reports of secretary and treasurer
4. Report of executive committee
5. Report of safety committee
6. Report of other committees
7. Unfinished business
8. Remarks by general manager
9. Remarks by vice president of administration
10. Remarks by sales managers
11. Remarks by general superintendent
12. Monthly cost analysis
13. New business
14. Speakers
15. Adjournment

During the meetings comparitive figures on monthly costs are submitted to the various superintendents and discussed. An estimate of future business is given by the sales manager.

These monthly contacts among men of the various quarries, the general office, and the sales force are very helpful in promoting a better understanding of each other's problems and create a spirit of ready cooperation between all departments. Social relationships and friendliness among the members of the association are furthered by an annual summer outing and a Christmas party.

Annual quarry costs per ton shipped

Distribution	1932	1933	1934	1935
Stripping	None	$0.0013	None	$0.0018
Drilling	$0.1105	.0590	$0.1016	.0950
Blasting	.0500	.0190	.0424	.0344
Loading	.1242	.0600	.0960	.0796
Transportation	.0371	.0348	.0447	.0319
Miscellaneous	.0071	.0007	.0025	.0061
Total quarry cost	.3289	.1748	.2872	.2488
Crushing	.1137	.0616	.0943	.0786
Screening and Conveying	.0431	.0229	.0302	.0197
Plant Miscellaneous	.0126	.0014	.0051	.0039
Total plant cost	.1694	.0859	.1296	.1022
Storage	.0538	.0119	.0309	.0302
Delivery	.0344	.0276	.0158	.0342
Total operating cost	.5865	.3002	.4635	.4154
Tons shipped	100,811	162,859	128,998	114,326

I - Summary of costs, 1930

Plainville quarry, New Haven Trap Rock Co.

Total material loaded during period: Overburden, 8,907 cubic yards.
Stone, 293,240 tons (2,000 lb.)

OPERATING COSTS PER DRY TON OF STONE MINED OR PER CU.YD. STRIPPING

Operation	Labor	Super-vision	Sundry ex-pense	Power cost	Fuel cost	Explo-sives cost	Other supplies	Total
Stripping:								
Loading	$0.0067	$0.0009			$0.0010		$0.0004	$0.0090
Transportation	.0019	.0002			.0003		.0005	.0029
Miscellaneous and repairs	.0006	.0001						.0007
Total stripping	.0092	.0012			.0013		.0009	.0126
Mining (per ton):								
Drilling:								
Primary	.0291	.0024		$.0021		$.0010	.0027	.0373
Secondary	.0309	.0020		.0062				.0391
Blasting:								
Primary	.0006	.0002				.0249		.0257
Secondary	.0074	.0006				.0161		.0241
Loading	.0353	.0020		.0165			.0272	.0818
Transportation	.0172	.0014			.0039		.0078	.0303
Miscellaneous and repairs	.0219	.0018			.0006		.0039	.0282
Total mining	.1424	.0112		.0248	.0045	.0420	.0416	.2665
Plant:								
Crushing	.0453	.0037		.0329			.0460	.1279
Storage in and out	.0134	.0011	.0157		.0041		.0193	.0536
Miscellaneous and repairs	.0337	.0027		.0004	.0003		.0039	.0410
Total plant	.0924	.0075	.0157	.0333	.0044		.0692	.2225
Total operating	.2440	.0199	.0157	.0581	.0102	.0420	.1117	.5016

II - Summary of costs in units of labor, power, and supplies, 1930

Plainville quarry, New Haven Trap Rock Co.

Material loaded during period:

Overburden, cubic yards, 8,907
Stone, tons, 293,240 - 186 lb. per cu. ft. in solid.
125 lb. per cu. ft. in loose.

	Stripping	Mining	Crushing	Other	Total
A. Labor (man-hours per ton of stone:					
Drilling		0.1166			0.1166
Blasting		.0067			.0067
Loading	0.0068	.0465			.0533
Haulage	.0046	.0286			.0332
Plant			0.0745		.0745
Miscellaneous maintenance and repairs	.0023	.0275	.0424	0.0110	.0832
Supervision	.0007	.0123	.0064		.0194
Total labor	.0144	.2382	.1233	.0110	.3869
Average tons per man per shift	.6255	37.8	72.9	.8181	23.14
Labor, percent of total cost	2.66	37.8	11.8	1.54	53.8
B. Power, supplies:					
Explosives (lb.per ton)		.3101			.3101
Total power (kw.-hr. per ton)		1.1489	1.5601	.0110	2.7200
1. Shovels		.7501			.7501
2. Air compressors secondary drilling		.2889			.2889
3. Drills primary		.1011			.1011
4. Pumping		.0088			.0088
5. Plant			1.5601		1.5601
6. Miscellaneous				.0110	.0110
Fuel (tons of coal per ton)	.0002			.0005	.0007
Other supplies in percent of total supplies and power	0.11	5.26	6.32	2.45	14.14

INSURANCE

Before 1934 insurance carriers covered the workmen of this plant for compensation. Because of the fine no-accident record of the various plants and the general increase in compensation rates on account of silicosis, the company adopted in 1934 self-insurace for all payments of compensation under the Workmen's Compensation Act of Connecticut. A certificate of "Solvency and financial ability to pay compensation directly to injured employees or other beneficiaries" was obtained from the compensation commissioner of each district in which plants of the company are operated. A reserve of 5 percent of each pay roll is set aside to take care of compensation payments, and a policy is carried insuring against all payments from $10,000 to $100,000 resulting from one accident.

All employees have been given a physical and X-ray examination, and no new employee is hired until a physical examination has been made. X-ray pictures are taken when the employee has worked for the company more than 6 months. Additional periodic check-ups are made when conditions warrant.

Fire insurance is carried on all buildings of the plant and their contents. Each building and its contents is insured within 80 percent of actual value with the "reduced rate contribution clause" applying.

A manufacturer's public liability policy covering any claim up to $50,000 as the result of an accident on the company property to any one person or $100,000 as the result of any one accident, is in effect. Amounts up to $25,000 are paid by another insurance carrier for any liability claims arising from steam-boiler or air-tank explosions.

Excess contingent coverage is also carried on any and all hired cars or trucks, also on the cars of all employees who may be sent out on company business, by an automobile liability policy carrying $50,000 and $100,000 personal liability and $5,000 property damage. This policy includes all company-owned vehicles operating on the highways.

Group accident and sickness policies are available for a nominal monthl charge to all employees of the company who have worked 1 year or more. Employees who have worked for the company 3 years are given a $500 life insurance policy, and no payment on this policy is required of the employee while he remains in the company's employ.